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Brief Communication: Twentieth-Century Replication of an Egyptian Mummy: Implications for Paleopathology

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ABSTRACT Replication in a modern human cadaver of ancient Egyptian mummification focused on tools used by ancient Egyptian embalmers, the use of natron (a mixture of sodium carbonate, bicarbonate, and chloride) in the preparation of the mummy, surgical procedures in the removal of the viscera and brain, and histologic examination of the viscera. The first three areas have been reported separately (Brier and Wade [1997] ZAS *124*:89–100). In this paper, we demonstrate a degree of histologic preservation comparable to that seen in Egyptian mummies, indicating the effectiveness of ancient mummification and that the histologic appearance of such mummies is little altered by the passage of millennia. Am J Phys Anthropol 107:417–420, 1998.

Interest in the examination of Egyptian mummies has seen significant growth over the past 30 years, coincident with the efforts of The Paleopathology Association (Cockburn, 1997), the Paleopathology Club of the U.S.-Canadian Academy of Pathology, and individual researchers. Previous experimental studies of mummification were limited to the desiccation and examination of small fragments of tissue (Zimmerman, 1972, 1977a), in which preservation was noted to be somewhat better than in actual mummies. There have been many reports of histopathology identified in Egyptian mummies, as compiled by Tyson (1997) and reviewed in Cockburn et al. (1998) and Aufderheide and Rodriquez-Martin (1998), but the unanswered question has been whether the appearance of the tissues of these mummies is due to the effects of the Egyptian mummification process alone or is modified by the passage of the several millennia following the labors of the ancient embalmers. A donated adult male cadaver was mummified in a fashion as closely as possible approximating ancient methods in an effort to answer this question (Brier and Wade, 1997).

The ancient Egyptians practiced mummification for more than 3,000 years. During that period, new techniques were introduced, old ones were refined, and, during Egypt's final decline, earlier procedures were forgotten and lost (Brier, 1994; Pettigrew, 1834; Smith and Dawson, 1991). Herodotus (1920) mentions that during the period he visited Egypt (circa 450 BC), there were three different mummification procedures according to price. Clearly, all Egyptian mummifications were not the same. In the modern mummification, the intention was to replicate a first-class mummification of the period at which the embalmers' art was at its peak. Thus, a royal mummification of the eighteenth dynasty was attempted.

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MATERIALS AND METHODS

The donor, an elderly male, died on the fifth day of hospitalization of heart failure and a clinically diagnosed massive myocardial infarction. The body was kept refrigerated for 36 h and then placed in a 0ûF freezer until removed for the study. The evisceration of the body was performed over a 16 h period at room temperature (70ûF) using a replica handmade embalming board and copper, bronze, and obsidian tools that had previously been prepared. Replicating ancient embalming technique, we eviscerated the body, not without some difficulty, through a small left lower quadrant abdominal incision, removing the spleen first and the liver last. The heart and brain were not examined in this study. In antiquity, the heart was left in the bodies, as part of funerary ritual, and the brain, the function of which was unknown to the ancient Egyptians, was discarded after extraction through the cribriform plate of the ethmoid bone or the foramen magnum. In this study, a hook was inserted through the nose in order to pulverize and remove the brain.

Natron (273 kg) had been imported for the study from the Wadi Natrun in Egypt. Natron is a naturally occurring compound of sodium carbonate and bicarbonate, with sodium chloride and sodium sulphate present as impurities. Twenty-nine 87 g linen packets of natron were used to pack the thoracic and abdominal cavities. A layer of natron was placed under the body on the board, and the remainder of the natron was used to cover the body, incidentally making clear the necessity for a wide embalming board.

The internal organs removed in this procedure, consisting of lungs, stomach, liver, spleen, pancreas, intestines, and kidneys, were placed in ceramic dishes, covered with natron, and placed at the corners of the embalming board. The cadaver and organs were kept in a 4 × 2.2 meter room at 115ûF and 28–30% humidity for 35 days.

RESULTS

Historical information (Herodotus, 1920) indicates a period of 30–40 days for embalming, as reviewed in Brier and Wade (1997). After 35 days, the body had a strong odor but not one of putrefaction. The natron formed large hard clumps, stained dark brown. Removal of the natron revealed a body appearing very similar to an ancient mummy. The skin was dried and dark brown, almost black. The limbs were initially flexible but became rigid and inflexible later. The facial features were shrunken but essentially unchanged. Some moisture did remain in the most dependent parts of the body, indicating that more natron should have been placed under the body. The eviscerated body had weighed 70.9 kg, and when removed from the natron it weighed 35.9 kg, a fluid loss of almost exactly half the body weight. The separately desiccated internal organs were completely dehydrated. The liver, although not brittle, was flat and nearly inflexible. There was no evidence of decomposition or putrefaction, and cultures of the mummified outer and inner body surfaces and the viscera for bacteria, fungi, and viruses were negative.

The histologic examination of mummified tissue is based on the use of Ruffer's solution (Ruffer, 1921), composed of 50 parts water, 30 parts absolute alcohol, and 20 parts 5% sodium carbonate. Adequate rehydration is generally achieved in 24–48 h, although tissue that is poorly preserved or extensively contaminated by bacteria tends simply to dissolve. Small (3 cm in the largest dimension) tissue specimens of the lung, liver, spleen, kidney, stomach, small intestine, colon, and gluteus maximus were rehydrated in Ruffer's solution for 36 h, fixed in absolute alcohol for 36 h, embedded in paraffin, and sectioned and stained by standard histologic techniques using hematoxylin and eosin (H&E) and several specific stains as noted below. The pathologist in this study (M.R.Z.) was not aware of the clinical history of the subject at the time he examined the tissue specimens.

Sections of the liver showed the general sinusoidal architecture and portal areas to be intact, with fine periportal fibrosis evidenced by a trichrome stain (Fig. 1). Nuclei were identified in many of the cells, varying from area to area. There was no evidence of primary or metastatic tumor. A few small bacterial colonies were seen.

The other organs were variably preserved. The pulmonary architecture was generally intact. As is usual in mummified remains, nuclei were poorly preserved. A minimal

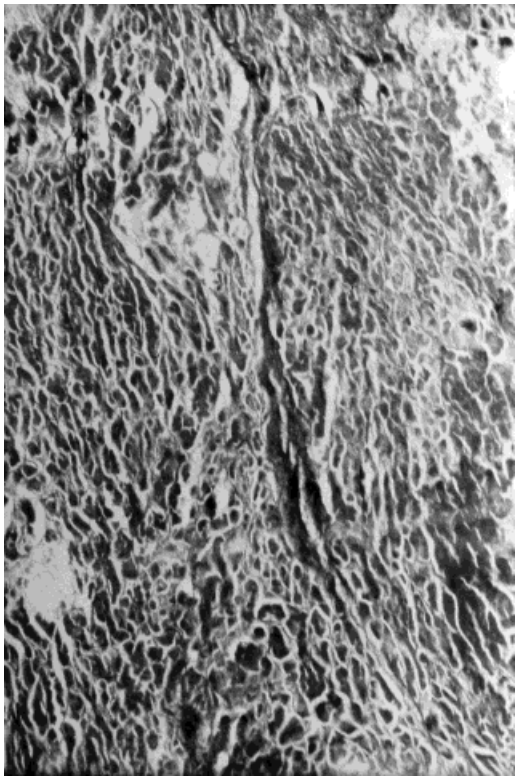

Fig. 1. Liver of the artificially prepared twentieth-century mummy, showing fibrosis. Trichrome stain. ×40

amount of anthracotic pigment was noted in the alveolar septae and some of the alveoli contained pink proteinaceous material, thought to be the residua of pulmonary edema. Several large pulmonary arteries were seen to be filled with blood. Phosphotungstic acid hematoxylin (PTAH) stain showed a blue meshwork consistent with thrombus material, as has been reported in experimentally mummified thrombi (Zimmerman, 1978). The general architecture of the spleen was well preserved, including the capsule, red and white pulp, and trabeculae. The kidneys were also well preserved, with glomeruli, tubules, vessels, and surrounding fat identified. An occasional thyroidized tubule was seen, suggesting old infection. The stomach was extraordinarily well preserved. The muscle wall and mucosa were intact, including the mucus-secreting glands of the stomach. On the other hand, the small and large intestines were poorly preserved, with loss of the mucosa and reduction of the muscularis to an eosinophilic mass. A section of the gluteus maximus showed poorly preserved muscle and fibroadipose tissue. Cross striations and nuclei were not seen with H&E stain and were barely seen with PTAH stain.

DISCUSSION

The general state of preservation of the organs in this experimental mummy was slightly better than but comparable to that of actual 1,800–3,200-year-old Egyptian mummies. The process of mummification appears to have resulted in good preservation of these organs, the histologic appearance being similar to that seen in previous smaller scale experimental studies of mummification (Zimmerman, 1972, 1978, 1979a). The differential preservation of most of the organs was about the same as ancient mummies, in that the lung and kidney were well preserved, the gluteus maximus fairly well preserved, and the small intestine and colon poorly preserved. The liver, spleen, and stomach were surprisingly well preserved, better than that seen in ancient mummies. In modern cadavers, the liver is usually autolyzed by migration of intestinal bacteria via the portal vein. In the experimental mummy, that process seems to have been partially arrested, probably by evisceration of the cadaver, and many of the liver cell nuclei, the portal areas, and pathologic change, consisting of periportal fibrosis, were identifiable. The pathology seen in the liver is remarkably similar to that of an actual Egyptian mummy (Fig. 2), a young man who died 3,200 years ago of a ruptured spleen secondary to schistosomal cirrhosis (Reyman et al., 1977; Zimmerman, 1990) and of modern patients with hepatic fibrosis, while the general appearance is similar to that of other Egyptian and frozen Alaskan mummies (Zimmerman, 1990; Zimmerman and Tedford, 1976; Zimmerman and Smith, 1975) and other experimentally mummified tissues (Zimmerman, 1972, 1977a). The preservation of the stomach is even more remarkable, in that the acidic contents produce rapid autolysis in modern cadavers, but this individual had died after more than 24 h of intravenous feeding, and the stomach was empty at the time of death. Elderly individu-

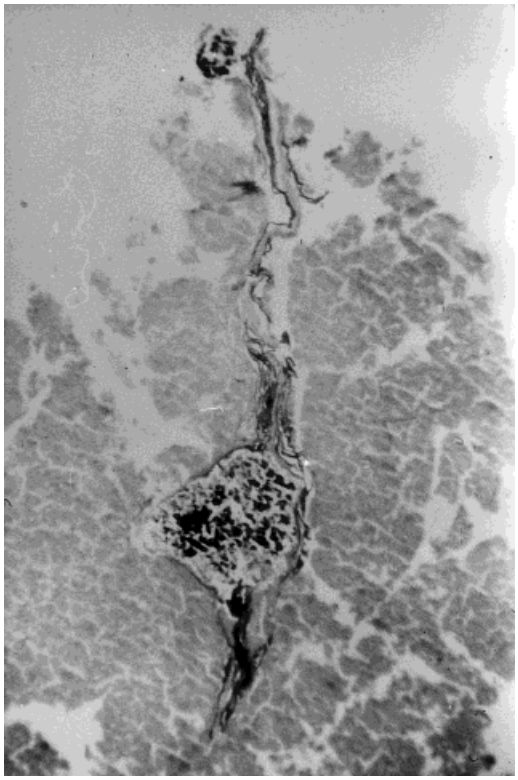

Fig. 2. Liver of a 3,200-year-old Egyptian mummy, showing schistosomal cirrhosis. Hematoxylin and eosin stain. ×40.

als often have decreased stomach acid levels as well.

We can now state that Egyptian mummification practices were quite effective and that there was probably little further degradation over the centuries (with the exception of mechanical disruption [i.e., tomb robbers or attack by insects]). It was also possible to make presumptive diagnoses in this individual of several pathologic processes, including pulmonary edema, pulmonary thromboemboli, hepatic fibrosis, and chronic pyelonephritis, the first three being related to the death of this individual due to chronic congestive heart failure, as was documented clinically. Pathologic changes affecting these organ systems in Egyptian mummies have previously been reported (Breutsch, 1959; Cockburn et al., 1998; Reyman et al., 1977; Tapp et al., 1975; Zimmerman, 1977b, 1976, 1990, 1993), and such diagnoses can now be viewed with confidence in both the efficacy of ancient Egyptian mummification practices and our diagnostic ability in examining ancient human remains.

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